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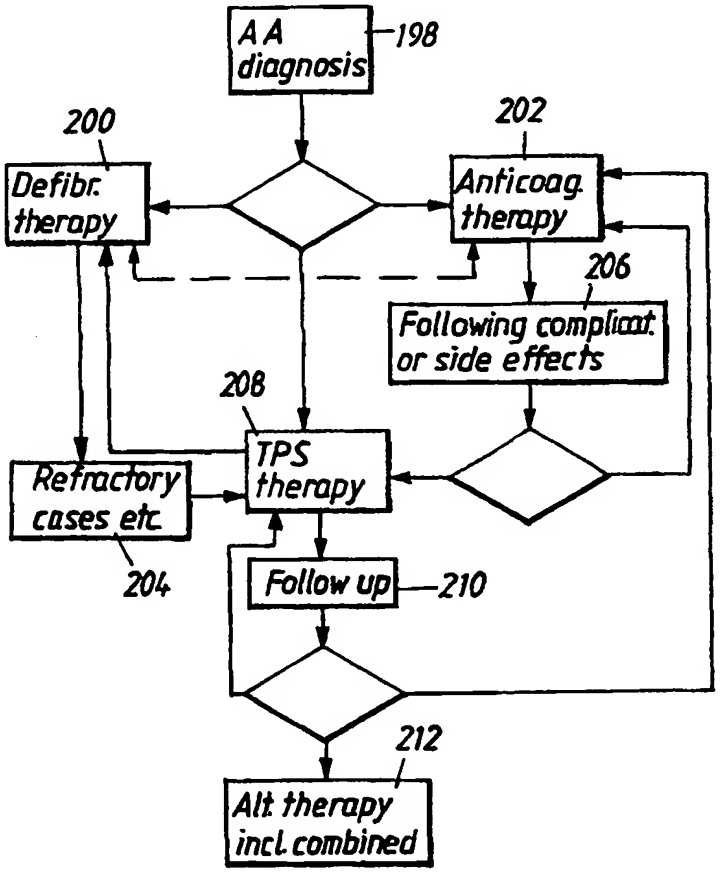
(57) Abstract

A heart stimulator comprises stimulation energy delivering means (200) intended to deliver stimulation energy through an implanted lead to the heart of a patient, and an atrial arrhythmia detecting means (198). A controlling means is provided to control said energy delivering means to deliver at least one atrial arrhythmia abolishing therapy and after a predetermined time, if continued atrial arrhythmia is detected, antithrombus stimulation energy pulses of lower energy than the defibrillation shock, but with different timing and with sufficient energy for producing atrial contraction for increasing hemodynamic blood transportation away from the atrium and preventing thrombi formation in the atrium. In case of a patient suffering from a chronic or paroxysmal non-curable atrial arrhythmia said controlling means is provided to control said energy delivering means to deliver antithrombus energy pulses without any preceding atrial defibrillation shock for electrical arrhythmia abolishing therapy.



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HEART STIMULATOR

1. Technical Field

The present invention relates to a heart stimulator comprising stimulation energy delivering means intended to deliver stimulation energy through at least one implanted lead to the heart of a patient and an atrial arrhythmia detecting means.

2. Background Art

2.1 Ethiology of Atrial Arrhythmia

There is a 2-4% prevalence of atrial fibrillation in humans around the age of 70 years. In case of chronic atrial fibrillation, paroxysmal atrial fibrillation, and other atrial arrhythmias there is a high risk of medical complications due to possible thrombi formations, such as embolism from the left side of the heart to cerebral arteries or to other arteries of the upper and lower part of the human body. In the case of thrombi formation in the right atrium or ventricle there is also a risk for accompanying embolism to the pulmonary vessels, with a risk of resulting pulmonary embolism.

2.2 Present Thromboprophylactic Therapy

Patients suffering from atrial arrythmia such as atrial fibrillation are often subject to medication with anti-thrombotic drugs, such as Dicumarol or Warfarine with the accompanying high risks of medical problems. Overdoses are associated with risks of bleeding, bruises and mental problems in relation to the elevated risk of bleeding etc., and undermedication is associated with a too low plasma concentration of Dicumarol and Warfarine with again an obvious risk of thrombi formation.

Moreover, there is a risk of low compliance to self-medication among these, often old, patients. The medication also requires frequent medical check-ups of, e.g. protrombine values, to be able to adapt the level of

medication to the needs of the drug metabolism in the individual patient. This means massively increasing medical care expenses. In addition thereto there are in quite a number of clinical cases contraindications to the use of drugs such as the ones mentioned above.

In spite of the frequent usage of the medical treatment described above there is no clear evidence as to the effectiveness of the treatment.

It is traditionally widely accepted that atrial thrombi form only after 2-3 days of atrial fibrillation, and that atrial thrombi in a fibrillating atrium form after the onset of the arrhythmia. Therefore, e.g. cardioversion of atrial fibrillation of less than 3 days duration without anticoagulation prophylaxis is believed to be safe and is commonly performed, see M.F. Stoddard, "Risk of Thromboembolism in New Onset or Transient Atrial Fibrillation", Progress in Cardiovascular Diseases, Vol. XXXIX, No. 1, July/August, 1996, pp. 69-80.

2.3 Biomedical Means for Atrial Conversion

An implantable atrial defibrillator specially designed for keeping the energy consumption on a comparatively low level is described in US-A-5,433,729, and US-A-5,464,429 discloses an apparatus for defibrillation of a heart, in which sequences of stimulation pulses and defibrillation shocks are delivered to the heart. The stimulation pulses used have an amplitude and/or pulse duration which greatly exceed the amplitude and/or pulse duration of ordinary pacemaker pulses, however, the high-energy stimulation pulses contain considerably less energy than an ordinary defibrillation shock, thereby reducing the total energy consumption.

In EP-A1 0 727 241 a device for electric heart stimulation is described, which device delivers a mild therapy to achieve an electrical influence on the heart which in a gentle manner reduces the occurrence of malfunctions in the muscles of the heart for correcting or restoring a collapsed conduction system.

In the following electrical thrombosis preventive stimulation or thromboembolic prophylactic stimulation is denoted by TPS and by thromboembolic prophylactic stimulation capture or TPS capture is meant a sufficient stimulation or energy level for achieving supporting hemodynamic blood transportation away from the atrium.

3. Disclosure of the Invention

The purpose of the present invention is to apply a heart stimulator for preventing or reducing thrombosis and embolism occurrence in case of atrial fibrillation or other atrial arrhythmia by an electrical therapy, said therapy not being intended for treatment of the atrial fibrillation or atrial arrhythmia in itself.

This purpose is obtained by a heart stimulator of the kind defined in the introductory portion and having the characterizing features of claims 1 or 2.

Thus, with the heart stimulator according to the invention an electrical prophylactic therapy is provided by electrical stimulation of heart tissue such that at least a partial contraction of the atrium is achieved with resulting improved hemodynamic blood transportation away from the atrium, where thrombi formation can be initialized. Thus the atrial contraction is not necessarily performed in an optimal physiological manner, but effective enough to protect the patient against thrombi formation and possible left or right sided embolic events. The heart stimulator according to the invention offers a comparatively cheap and easily performed therapy of the above discussed universally spread disease. Another advantage of the heart stimulator according to the invention is that it can be easily realized by modifying existing pacemaker and defibrillator apparatuses.

The heart stimulator according to the invention can suitably be used for providing thromboprophylactic electrical stimulation of the atrium when ordinary defibrillation therapy has not been successful within 2-3 days after the onset of the atrial arrhythmia, as

discussed above. The heart stimulator according to the invention can also be used for delivering the thromboprophylactic therapy to patients having chhronic or paroxysmal, non-cureable atrial fibrillation. The therapy delivered by the heart stimulator according to the invention can also be a supplement to thromboprophylactic medication.

The antithrombus stimulation energy pulses delivered by the stimulator according to the invention are of lower energy than a defibrillation shock, but, according to an advantageous embodiment of the invention, of sufficient magnitude for causing a contraction in at least a part of atrial muscular tissue. Thus, the thromboprophylactic therapy delivered by the heart stimulator according to the invention is considerably less energy consuming than a regular defibrillation therapy.

According to an advantageous embodiment of the heart stimulator according to the invention said stimulator comprises a control means which in its turn includes a synchronizing means which is adapted to control the energy delivery means to deliver antithrombus stimulation energy in a phase of the cardiac cycle sufficiently separated from the vulnerable phase of the cycle. In this way the patient is protected against the triggering of dangerous cardiac events.

The heart stimulator according to the invention can comprise a pacemaker or a defibrillator having different modes of operation, one of said modes being a thrombo-prophylactic stimulation mode for delivery of antithrombus stimulation energy.

4. Brief Description of the Drawings

To explain the invention in greater detail embodiments of the heart stimulator according to the invention, chosen as examples, will now be described with reference to the enclosed drawings on which

Fig. 1 schematically shows a first embodiment of the heart stimulator according to the invention in the

form of a DDD-pacemaker modified to include a special antithrombus stimulation mode of operation,

Fig. 2 is a normal DDD therapy ECG,

Fig. 3 - 5 show corresponding diagrams for different examples of thromboprophylactic stimulation by the stimulator in fig. 1,

Fig. 6 shows schematically a second embodiment of the heart stimulator according to the invention in the form of a VDD pacemaker provided with an antithrombus stimulation mode of operation,

Fig. 7 shows a typical example of an ECG illustrating the operation of the embodiment shown in fig. 6,

Fig. 8 shows schematically a third embodiment of the heart stimulator according to the invention in the form of a VVI pacemaker provided with an antithrombus stimulation mode of operation,

Fig. 9 shows an ECG for the heart stimulator in fig. 8 operating in a normal pacing mode,

Fig. 10 shows an ECG for the heart stimulator in fig. 8 operating in the antithrombus stimulation mode of operation,

Fig. 11 is an ECG for an antithrombus stimulation mode of operation integrated with ordinary pacing stimulation,

Fig. 12 shows an ECG in case of antithrombus stimulation in the form of bursts or strong crosstalk stimuli,

Fig. 13 shows schematically a fourth embodiment of the heart stimulator according to the invention in the form of an atrial defibrillator provided with an antithrombus stimulation mode of operation,

Fig. 14 is a flow diagram illustrating the ordinary operation of the heart stimulator shown in fig. 13,

Fig. 15 is a flow diagram illustrating the antithrombus stimulation mode of operation of the heart stimulator in fig. 13,

Fig. 16 shows schematically a fifth embodiment of the heart stimulator according to the invention in the form of a dual chamber defibrillator provided with a thromboembolic prophylactic stimulation means,

Fig. 17 shows schematically a sixth embodiment of the heart stimulator according to the invention including a device for delivering DC thromboembolic prophylactic current injection,

Fig. 18 shows an ECG recorded during operation of the heart stimulator in fig. 17,

Fig. 19 shows schematically a seventh embodimenet of the heart stimulator according to the invention including a multisite thromboembolic prophylactic stimulation device,

Fig. 20 shows schematically an eighth embodiment of the heart stimulator according to the invention provided with a multisite and/or multichamber thromboembolic prophylactic stimulation device,

Fig. 21 is a block diagram illustrating the operation of a conventional pacing system provided with a mode switch,

Fig. 22 is a block diagram illustrating the operation of a heart stimulator according to the invention including a conventional pacing system with TPS electronics,

Fig. 23 is a block diagram illustrating the operation of a heart stimulator according to the invention without a pacing system, and

Fig. 24 is a flow chart exemplifying the therapy decision making in connection with a heart stimulator of the type shown in fig. 23.

5. Description of Preferred Embodiments

As mentioned above the heart stimulator according to the invention can easily be realized by modifying

currently existing heart stimulator designs and current electrode positioning of implantable systems can be used. Contractive stimulus for thromboembolic prophylactic therapy can thus be applied directly in the right atrium, epicardially on the right and/or left atrial wall, in the coronary vein system, in and on the right ventricular wall or epicardially on the left ventricular wall. The electrode placement could be atrial appendix, atrial lateral wall, atrial septum, coronary sinus or in the upper portion of the right ventricle, preferably in the outflow tract. The thromboembolic prophylactic stimulation can be provided in the form of a contractive electrical stimulus of an energy below the defibrillation threshold value. Such low energy defibrillation or electrical convertion can be used in a crosstalk manner in the heart stimulator according to the invention. Thus a low-energy electrical ventricular stimulus of an amplitude below defibrillation therapy level can cause atrial contraction without major disturbance or side effects on the heart rhythm.

An atrial shock stimulus with or without "defibrillation capture" can be applied for thromboembolic prophylactic stimulation by the heart stimulator according to the invention. Such atrial shock stimulus can be applied directly on the right or left atrium or as interatrial crosstalk. Thromboembolic prophylactic stimuli can also be applied in the right ventricle as ventriculo-atrial crosstalk.

The heart stimulator according to the invention can also deliver thromboembolic prophylactic therapy in the form of an electric DC stimulation of heart tissue of the general kind described, however for other purposes, in the above mentioned EP-A1-0 727 241.

As mentioned above the heart stimulator according to the invention can comprise an ordinary pacemaker or defibrillator modified to deliver thromboembolic prophylactic stimulation. The heart stimulator according to the invention can, however, as well be realized as an

apparatus just for cardiac related management of thromboembolic risks and their treatment.

The thromboembolic prophylactic therapy can be applied in an automatically programmed mode or induced by a physician and/or by the patient himself or herself. The thromboembolic prophylactic therapy can be applied in varying set-ups depending on the condition of the heart conduction system of the individual patient.

The thromboembolic prophylactic stimulation can consist of a combined DC and pulsed heart tissue stimulation too. Fig. 1 shows a first embodiment of the heart stimulator according to the invention comprising a DDD pacemaker 2 connected through leads 4, 6 to the right atrium 8 and the right ventricle 10 respectively of the heart 12 of a patient. The stimulator 2 is devised for delivering thromboembolic prophylactic stimulation pulses in the atrium and in the ventricle. In the ventricle a crosstalk stimulation is used for the thromboembolic prophylactic therapy. The atrial electrode tip 14 can be positioned in the atrial appendage, in the lateral cardiac wall or in the cardiac septal wall as shown in the figure.

The heart stimulator 2 delivers in the thromboembolic prophylactic mode bursts of pulses or high voltage stimulation pulses in the atrium, c.f. figs. 3 and 4. In addition thereto pacing is performed in VVI mode or atrial pace inhibition mode with thromboembolic prophylactic crosstalk stimuli in the ventricle.

Fig. 2 shows the ECG for normal DDD pacing therapy disclosing an atrial pacing stimulation pulse A, the P-wave, a ventricular pacing stimulation pulse V, the QRS-complex and the T-wave.

Fig. 3 shows the ECG in a mode of operation in which the heart stimulator according to figure 1 delivers a burst of thromboembolic prophylactic stimulation pulses TPS followed by a ventricular stimulation pulse V. As appears from this diagram an atrial stimulation pulse A does not result in atrial capture, i.e. no P-wave is

observed at 15 but a state of atrial fibrillation AF continues.

Fig. 4 shows the ECG for a mode of operation in which a strong high voltage thromboembolic prophylactic stimulation pulse TPS is delivered followed by a ventricular stimulation pacing pulse V. The thromboembolic prophylactic stimulation pulse TPS is a strong stimuli and has the character of an "extended" pacing pulse or atrial DC pulse.

The therapies illustrated in figs. 3 and 4 can also be combined, even in the same patient.

Fig. 5 shows an ECG for a mode of operation in which the application of thromboembolic prophylactic stimulation bursts TPS are separated by a plurality of RR-intervals, possibly including spontaneous heart activity with inhibited pacing and thromboembolic prophylactic treatment as indicated to the left of the figure. Bursts of thromboembolic prophylactic stimulation pulses TPS can typically be delivered a couple of times per 24 hours.

The result of the thromboembolic prophylactic therapy can be arrhythmia management or improval too, but this is not the main purpose, as discussed above.

Fig. 6 shows a second embodiment of the heart stimulator according to the invention comprising a VDD pacemaker designed for atrial activity detection and thromboembolic prophylactic crosstalk stimulation in the ventricle.

Thus a sensor 18 is located in the atrium 8 and when an arrhythmia is sensed by this sensor 18, at 20 in fig. 7, without the appearance of a P-wave, thromboembolic prophylactic crosstalk stimulation TPS is delivered to the ventricle in the form of a high-voltage pulse or burst of pulses during the refractory period of the ventricle Ref in fig. 7.

For this embodiment special electrode positions, at 21 in figure 6, could be necessary such as the right ventricular outflow tract or close to the valvular area.

In fig. 8 a third embodiment of the heart stimulator 22 according to the invention is shown, including a VVI pacemaker and means for atrial fibrillation detection.

Detection of atrial fibrillation can be made e.g. from R-R interval variations during the detection period. Thus atrial fibrillation can be indicated if e.g. the mean value of the RR intervals RR_{mean} is much less than a RR_{crit} denoting a critical value for atrial fibrillation.

In case of no detected atrial arrhythmia there is no need for thromboembolic prophylactic therapy and pacing in the VVI-mode is performed according to the ECG shown in fig. 9. In case of detection of atrial fibrillation, $t1 \neq t2 \neq T$, periods of atrial fibrillation being denoted by AF in fig. 10, thromboembolic prophylactic therapy is delivered in the form of bursts of thromboembolic prophylactic stimulation pulses in the non-vulnerable phase of the cardiac cycle, shown at 24 in the ECG in fig. 10. In this case the thromboembolic prophylactic stimulation mode is applied according to a separate variability criteria. The thromboembolic prophylactic stimulation can also comprise delivery of high-voltage stimulation pulses. These pulses or bursts of pulses are delivered in the refractory period as mentioned above.

Fig. 11 shows an ECG illustrating a situation in which the thromboembolic prophylactic stimulation, in the form of a single high-voltage pulse 28, is integrated with pacing stimulation delivered in the ventricle with a heart stimulator according to figures 6 or 8. The pulse 28 thus constitutes an extended, supra threshold stimulation. An ordinary pacing pulse is shown at 26.

Fig. 12 shows the ECG in a situation with bursts of thromboembolic prophylactic stimulation pulses, at 30, the amplitude of the burst pulses being lower than the amplitude of an ordinary stimulation pulse 26, or strong thromboembolic prophylactic crosstalk stimuli 32, cf. figure 11.

Fig. 13 shows a fourth embodiment of the heart stimulator according to the invention including an atrial defibrillator. This defibrillator is disposed such that, if atrial fibrillation or atrial tachycardia is detected, a shock of lower energy than an ordinary defibrillation shock is delivered periodically as thromboembolic prophylactic stimulation for improvement of blood circulation and turnover. The thromboembolic prophylactic stimulation function is inhibited if the atrial rhythm is normalized, e.g. sinus rhythm is detected, and the thromboembolic prophylactic stimulation function is activated in case of unsuccessful atrial defibrillation therapy. The thromboembolic prophylactic stimulation therapy is controlled to be applied temporally separated from the ventricular vulnerable phase of the cardiac cycle, as mentioned above. The thromboembolic prophylactic stimulation function is synchronized to the cardiac cycle such that optimized left and right atrial blood drainage is accomplished.

The atrial defibrillator 34 thus comprises a defibrillator unit DEF and a pacemaker P for stimulation in the ventricle. A control unit 36 is connected to the pacemaker P and the defibrillator DEF for controlling the delivery of thromboembolic prophylactic stimulation in response to sensed state of the heart. The defibrillator also comprises electronics 37, containing e.g. memories, programs for thromboembolic prophylactic stimulation etc.The defibrillator DEF is connected through leads 38, 40, to atrial defibrillation electrodes 44, 46 and the pacemaker P is connected through leads 42, 43, 47 to electrodes in the atrium 49 and the ventricle 48, 50 respectively. The defibrillator is communicating with an external programmer in the normal way by telemetri.

Fig. 14 shows a block diagram illustrating normal defibrillation. Thus when detecting atrial fibrillation, no P-wave, at block 52, defibrillation therapy is applied, at block 54. As a result of this therapy the heart resumes its normal atrial rhythm and P-waves appear, at block 56.

If atrial defibrillation is detected, block 52 in figure 15, a defibrillation therapy is delivered, at block 54. If a P-wave is detected as a result of the therapy atrial or ventricular Astim or Vstim is delivered in traditional therapies by the output block 55.If no P-wave is detected as a result of the defibrillation, block 54, this information is sent to a counter 57 and if "no P-wave" appears a predetermined number of times n a time delay, block 59, is started and a warning, block 61, is given. If no P-wave appears within a predetermined time delay, such that "no P-waves" appear n + 1 times the output block 55 is controlled by a TPS control block 63 to deliver thromboembolic prophylactic therapy. The thromboembolic prophylactic therapy can be selectable via a program structure, in block 55, or a physician can be able to use a real time controlled "open" loop to select e.g. the number and pattern of thromboembolic prophylactic stimuli and the time between each stimulation event.This new therapy can be combined with the traditional ones.

If a P-wave appears during the mentioned predetermined time delay the output block 55 is controlled to deliver traditional therapies.

Figure 16 shows a fifth embodiment of the heart stimulator according to the invention including a dual chamber defibrillator. Thus this heart stimulator 62 comprises a defibrillator unit DEF, a pacing unit PACE and a thromboembolic prophylactic stimulation unit TPS. The pacing unit PACE is connected via leads 64, 66, 68 to electrodes 70 for atrial pacing in coronary sinus and ventricular electrode poles 72, 74. The defibrillator unit DEF is connected through leads 76, 78, 80 to electrodes in the coronary sinus 82, in the superior vena cava 84 and in the right ventricle 86 respectively.

m denotes memory and telemetric means for communication with an external programming unit.

The thromboembolic prophylactic therapy can be applied on the atrium similar to anti-tachycardia therapy using pulses with voltages above the pacing stimulation

pulse level. The thromboembolic prophylactic therapy can be applied simultaneous with AV-defibrillation, or together with pacing therapy of the patient by mode switching between the different modes of operation of the heart stimulator 62.

In fig. 17 a sixth embodiment of the heart stimulator according to the invention is shown. The stimulator 88 comprises a defibrillator unit DEF, a pacing unit PACE, a DC-voltage source 90 connected to a unit 92 for delivering thromboembolic prophylactic therapy. The stimulator 88 is connected through a lead 94 to the atrium 8 of the heart 12 for delivering thromboembolic prophylactic DC current injection therapy to the right atrium 8.

The electrode system can be similar to the electrode system of a pacing device or an atrial defibrillator system.

The treatment of the heart tissue with DC as a thromboembolic prophylactic therapy can be performed with different characteristics. Fig. 18 shows an ECG with one example of DC energy delivery during a comparatively long time, at 96, and during a shorter time, at 98.

By DC energy or DC therapy is meant that kind of mild therapy defined in the previously mentioned EP-A1 0 727 241.

The stimulator in fig. 17 can also be of an atrio-ventricular setup with electrodes for the thromboembolic prophylactic therapy similar to the electrodes of a dual chamber defibrillator system, and the pacing unit PACE can be adapted for stimulation both in the atrium and the ventricle. The ECG in fig. 18 shows the delivery of both atrial pacing pulses A and ventricular pacing pulses V.

The DC energy and other types of TPS therapies can be delivered between two selectable electrodes which can be implantable transvascular or extravascular electrodes, including epicardial electrodes.

Figs. 19 and 20 show two more modifications of the stimulator shown in fig. 17 for multisite and/or multichamber thromboembolic prophylactic stimulation. These embodiments of the heart stimulator according to the invention comprise a defibrillator unit 100, a pacing unit 102, a DC voltage unit 104 and a thromboembolic prophylactic stimulation unit 106 as in the embodiment shown in fig. 17. The stimulator further comprises a multisite unit 110 for connecting the stimulator 108 to a plurality of electrode leads 112, 114, 116, 118. In the embodiment shown in fig. 19 the stimulator 108 is connected to the heart 12 through four electrode leads 112, 114, 116, 118 with epicardial electrodes 120, 122, 124, and 126 respectively. Thus with this embodiment multisite thromboembolic prophylactic stimulation can be provided.

Fig. 20 shows an alternative embodiment for providing multisite unichamber thromboembolic prophylactic stimulation. Thus thromboembolic prophylactic stimulation of the atrium 8 can be applied through the leads 128, 130, 132,. In addition thereto the stimulator 108 is connected to the ventricle 10 through a lead 134 for ventricular stimulation (and possibly sensing).

The shown multisite atrial electrode array can be realized as one multipolar atrial electrode.

In these embodiments different kinds of therapy (pacing, defibrillation, thromboembolic prophylactic therapy) can be performed simultaneously or sequentially.

The described embodiments of the heart stimulator according to the invention can deliver thromboembolic prophylactic therapy of different kinds. Thus the thromboembolic prophylactic stimulation can comprise ordinary "standard" pacing pulses with amplitudes and/or energies below pacing threshold values, equal to the pacing threshold value or above this threshold value. The thromboembolic prophylactic stimulation can consist in burst therapy similar to the therapy delivered by known antitachy pacing systems. The thromboembolic prophylactic

stimulation can comprise pacing with DC voltage and/or "defibrillator therapy". The defibrillation therapy is then performed with energy levels below those of ordinary defibrillation, but mostly above pacing stimulation energy levels in atrium and ventricle. The thromboembolic prophylactic stimulation capture is obtained when the stimulation or energy level is sufficient for achieving or supporting haemodynamic blood transportation away from the atrium. Relevant TPS capture is verified by the physician during implantation or follow-up procedures. Current technique for such evaluation is e.g. fluoroscopy, echocardiography, ultrasound doppler measurements, and atrial related ECG pattern changes.

Fig. 21 shows a block diagram of a conventional pacing system with mode switch comprising pacing electronics 138 and a sensing unit 140. By atrial and ventricular detectors 142 and 144 respectively the status of the atrium - atrial arrhythmia 146, atrial stimulation 148 and sensed P-wave 150 - and of the ventricle - QRS complex 152 or ventricular stimulation 154 - are detected. In case of P-wave detection, block 150, and QRS complex detection, block 152, no stimulation is given to the heart, block 156. In case of atrial and ventricular stimulation the pacing system is operating in a DDD mode, block 158, and its operation is fed back through the block pacing therapy 160 to the sensing unit 140.

An event memory 162 is also connected to the sensing unit 140 for storing sensed cardiac events.

In case of detection of atrial arrhythmia the mode of operation is switched to a VVI mode, blocks 164, 166.

Fig. 22 shows a heart stimulator according to the invention including a pacing system of the type shown in fig. 21 and provided with means for thromboembolic prophylactic therapy. Thus block 168 represents the pacing system in fig. 21. Atrial arrhythmias are detected by an atrial detector 170. Atrial arrhythmias can, however, also be jointly detected in the ventricle from R-R interval

variations, blocks 172, 174. t_1 denotes a time constant for therapy interval programming, block 176. This time constant t_1 can vary from once every second R-R interval to twice daily.

The informations from block 170 about possible detected atrial arrhythmias together with information from block 174 about the detected R-R variability and synchronizing informations from block 178 and the time constant t_1, block 176, are supplied to the summing unit 180, which in response to these informations controls the thromboembolic prophylactic stimulation means 182. The resulting operation of the thromboembolic prophylactic stimulation means 182 is stored in a memory 184 and this information is fed back to the pacing system 168. The memory 184 is also connected to the cardiac event memory 186 which in its turn is connected to the pacing system 168, too.

t_2, block 188, denotes a time constant for switching from active thromboembolic prophylactic therapy mode into a supervising mode in case of detected atrial arrhythmia inhibition, block 190.

An external programmer 192 is by telemetric means 194 communicating with the pacing system 168 in a conventional manner. Programmable parameters are magnitudes of the time constants t_1 and t_2, pulse morphology, pulse shape (slew rate, decay time), pulse width, pulse amplitude, pulse sequence, pulse burst or no pulse burst, pulse burst morphology and different therapeutic intervals.

Patients previously not equipped with a pacemaker system or a defibrillator will receive a heart stimulator according to the invention just including a special thromboembolic prophylactic stimulation device as illustrated in fig. 23. This embodiment is similar to the embodiment shown in fig. 22 with the exception that there is no pacing system 168. For controlling the operation of this heart stimulator sensing electronics 196 and controlling electronics 198 are provided for controlling

the operation in response to received informations. For the rest the same reference numerals are used as in fig. 22.

Fig. 24 is a flow chart illustrating the therapy decision making according to the invention for an atrial arrhythmia patient..

In case of atrial arrhythmia diagnosis 198 defibrillating therapy 200 and/or an anti-blood coagulation therapy 202 are applied. If the patient is not positively responding to the defibrillating therapy, block 204, and/or if there are complications or undesirable side effects from the anti-coagulation therapy, thromboembolic prophylactic stimulation therapy delivered by the heart stimulator according to the invention is applied after suitable time delays, block 208. The result of this therapy is followed up, block 210, and fed back to the thromboembolic prophylactic stimulation means, block 208, for possibly modifying the therapy. Depending on the results of the thromboembolic prophylactic therapy also alternatives, including combinations of different therapies, can be considered, block 212.

Thus by using e.g. a pacemaker lead of conventional uni- or bipolar type, placed in the right atrium of the heart or epicardially at the left atrium it is possible with a heart stimulator according to the invention to stimulate the left atrium to contract periodically in order to prevent thrombous formation in an atrium of regular size or in a dilated atrium. With the heart stimulator according to the invention the need for anticoagulent or related antithrombotic medication is reduced. It also reduces the need for electroconvertion with its risks, costs and ineffectiveness.

The therapy applied by the heart stimulator according to the invention consists in a more "powerful stimulation" than ordinary pacing stimulation in order to achieve an intermittent antithrombotic contractive therapy.

The decision for implementing the thromboembolic prophylactic therapy by the heart stimulator according to the invention is in the individual case to be taken by the physician. The therapy can be implemented by an automatic adaptive algorithm or by a custom defined therapy program with selectable semi-automatic limitations (stimulation period during day or night, number and morphology of consecutive pulses during the stimulation period, etc.), safeguarding escape mode in case of ventricular arrhythmia detection, and by program selectable time limiting supervising mode at detection of recurrent normal atrial sinus rhythm, e.g. in paroxysmal atrial fibrillation. Usually the thromboembolic prophylactic therapy is applied after about a 24 hour period of atrial arrhythmia, e.g. atrial fibrillation.

The heart stimulator according to the invention comprises at least one thromboembolic prophylactic stimulation electrode and possibly at least one sensing electrode. The sensing electrode is not necessarily implanted in the heart and/or on the heart, however, it is to be positioned for best P-wave and QRS detection and monitoring, which also includes multisite setup electrode applications as described above.

The risk of thrombous formation can be determined by pressure, flow and doppler measurements. By forming an average value of the ECG signal, especially in relation to the P-wave, during a plurality of cardiac cycles before the thromboembolic prophylactic therapy, and after this therapy the difference between these average values gives an indication of the effect of the therapy. Sometimes the trembling motion of a fibrillating atrium seem to promote thrombous formation.

Claims

1. A heart stimulator comprising stimulation energy delivering means intended to deliver stimulation energy through at least one implanted lead to the heart of a patient and an atrial arrhythmia detecting means, **characterized in** that a controlling means is provided to control said energy delivering means to deliver at least one atrial arrhythmia abolishing stimulus and after a predetermined time, if continued atrial arrhythmia is detected, antithrombus stimulation energy pulses of different timing and energy levels than the primary stimulus but with energy enough for producing an atrial contraction that promotes the efficiency of hemodynamic blood transportation away from the atrium and preventing thrombi formation in the atrium.

2. A heart stimulator for thromboprophylactic electric stimulation of the atrium of a patient suffering from a chronic or paroxysmal non-cureable atrial arrhythmia, comprising stimulation energy delivering means intended to deliver stimulation energy through at least one implanted lead to the heart of a patient and an atrial arrhythmia detecting means, **characterized in** that a controlling means is provided to control said energy delivering means to deliver antithrombus stimulation energy pulses of lower energy than an ordinary defibrillation shock but of sufficient energy for producing atrial contraction for increasing hemodynamic blood transportation away from the atrium and preventing thrombi formation in the atrium.

3. The heart stimulator according to claims 1 or 2, **characterized in** that a time delay means is provided for delaying the delivery of antithrombus stimulation energy a

predetermined time after the detected onset of an atrial arrhythmia or after the terminated unsuccesful therapy of an atrial arrhythmia.

4. The heart stimulator according to claim 3, **characterized in** that said time delay is programmable.

5. The heart stimulator according to claims 3 or 4, **characterized in** that said predetermined time delay is at least 24 hours.

6. The heart stimulator according to claim 1, **characterized in** that said control means is manually actuatable for manual determination of the time of antithrombus stimulation energy delivery.

7. The heart stimulator according to any of the preceding claims, **characterized in** that said atrial arrythmia detecting means comprises a P-wave detector.

8. The heart stimulator according to any of the claims 1 through 6, **characterized in** that said atrial arrythmia detecting means comprises means for detecting atrial arrythmia from sensed R-R interval variations.

9. The heart stimulator according to any of the preceding claims, **characterized in** that said energy delivering means is controllable to deliver antithrombus stimulation energy in the form of bursts of antithrombus stimulation pulses.

10. The heart stimulator according to any of the preceding claims, **characterized in** that the energy of said antithrombus stimulation pulses or bursts of pulses is

sufficient for causing a contraction in at least a part of the atrial muscular tissue.

11. The heart stimulator according to any of the claims 7 through 10, **characterized in** that a programming means is provided for programming the morphology of antithrombus stimulation pulses or bursts of pulses.

12. The heart stimulator according to claim 11, **characterized in** that said programming means is adapted for programming the time interval between consecutive antithroumbus stimulation pulses or consecutive bursts of antithroumbus stimulation pulses.

13. The heart stimulator according to any of the preceding claims, **characterized in** that said energy delivering means is controlled to deliver antithrombus stimulation energy as injection of DC current in the heart tissue.

14. The heart stimulator according to any of the preceding claims, **characterized in** that said energy delivering means is controllable to periodically deliver antithrombus stimulation energy.

15. The heart stimulator according to claim 14, **characterized in** that said energy delivering means is controllable to deliver antithrombus stimulation energy with a frequency between twice a day and each second heart beat.

16. The heart stimulator according to any of the preceding claims, **characterized in** that said control means comprises a sychronizing means for synchronizing said antithrombus

stimulation energy delivery to the cardiac cycle to optimize atrial drainage.

17. The heart stimulator according to claim 16, **characterized in** that said sychronizing means is adapted to control said energy delivery means to deliver said antithrombus stimulation energy in a phase of the cardiac cycle separated from the vulnerable phase of the ventricle.

18. The heart stimulator according to claims 16 or 17, **characterized in** that said sychronizing means is adapted to control said energy delivery means to deliver a plurality of single antithrombus stimulation pulses or bursts of pulses, said pulses or bursts of pulses being separated by a plurality of cardiac cycles.

19. The heart stimulator according to any of the claims 16 through 18, **characterized in** that said sychronizing means is adapted to control said energy delivery means to deliver single antithrombus stimulation pulses or bursts of pulses before the QRS complex in the cardiac cycle, preferably at the normal location of a P-wave.

20. The heart stimulator according to any of the preceding claims, **characterized in** that the stimulator is devised for delivering energy for antithrombus therapy between two selectable electrodes which are implantable transvascular or extravascular electrodes, including epicardial electrodes.

21. The heart stimulator according to any of the preceding claims, **characterized in** that the stimulator is devised

for connection to an electrode lead of uni- or bipolar type, designed for implantation into the atrium.

22. The heart stimulator according to any of the claims 1 through 20, **characterized in** that the stimulator is devised for connection to an electrode lead designed for implantation into the coronary vein system including coronary sinus ostium area.

23. The heart stimulator according to any of the claims 1 through 20, **characterized in** that the stimulator is devised for connection to an electrode lead is designed for implantation into or on the right ventricular wall.

24. The heart stimulator according to claim 23, **characterized in** that said stimulation energy delivering means is adapted for delivering, via a lead implantable in the right ventricle, antithrombus stimulation pulses or bursts of antithrombus stimulation pulses as ventriculo-atrial crosstalk.

25. The heart stimulator according to claim 24, **characterized in** that said antithrombus stimulation energy delivering means is controllable to deliver said crosstalk antithrombus stimulation pulses or said crosstalk bursts of antithrombus stimulation pulses in the time interval between the QRS- complex and the T-wave.

26. The heart stimulator according to any of the claims 1 through 20, **characterized in** that the stimulator is devised for connection to an atrial multipolar electrode lead for multisite antithrombus therapy of the atrium.

27. The heart stimulator according to any of the claims 1 through 20, **characterized in** that the stimulator is devised for connection to a plurality of electrode leads for multisite epicardial antithrombus therapy.

28. The heart stimulator according to claim 27, **characterized in** that said plurality of leads is adapted for unichamber antithrombus therapy.

29. The heart stimulator according to claim 27, **characterized in** that said plurality of leads is adapted for multichamber antithrombus therapy.

30. The heart stimulator according to claim 27, **characterized in** that said plurality of electrode leads comprises epicardial electrodes for implantation on the right and/or left atrial wall and/or on the right and/or left ventricular wall.

31. The heart stimulator according to any of the claims 1 through 20, **characterized in** that said stimulation energy delivering means is adapted for delivering, via a lead implantable in the left atrium, antithrombus stimulation pulses or bursts of antithrombus stimulation pulses as inter-atrial crosstalk.

32. The heart stimulator according to any of the claims 1 through 20, **characterized in** that said stimulation energy delivering means is adapted for delivery, via an implantable lead, of antithrombus stimulation energy in the right ventricle outflow tract or in the vicinity of the valvular area.

33. The heart stimulator according to any of the preceding claims, **characterized in** that said stimulator comprises a pacemaker.

34. The heart stimulator according to claim 33, **characterized in** that said pacemaker has different modes of operation, one of said modes being a thromboprophylactic stimulation mode for delivery of antithrombus stimulation energy.

35.The heart stimulator according to claims 33 or 34, **characterized in** that said energy delivering means is controllable to deliver a combined pacing stimulation and antithrombus stimulation pulse intended to be delivered to a lead implantable in the right ventricle.

36. The heart stimulator according to any of the preceding claims, **characterized in** that said stimulator comprises a defibrillator.

37. The heart stimulator according to claim 36, **characterized in** that said defibrillator is an atrial defibrillator.

38. The heart stimulator according to claims 36 or 37, **characterized in** that said defibrillator is a dual-chamber defibrillator which is switchable between a defibrillation mode of operation and an antithrombus therapy mode of operation.

39. The heart stimulator according to claims 36 or 37, **characterized in** that said energy delivering means is controllable to deliver antithrombus energy in bursts of pulses similar to defibrillation or cardioversion bursts

of pulses for atrial and ventricular antiarrhythmic therapy.

40. The heart stimulator according to any of the claims 36 through 39, **characterized in** that said stimulation energy delivering means is controllable to deliver antithrombus stimulating —DC current injection in cardiac tissue combined with antiarrhythmic therapy.

Fig.1

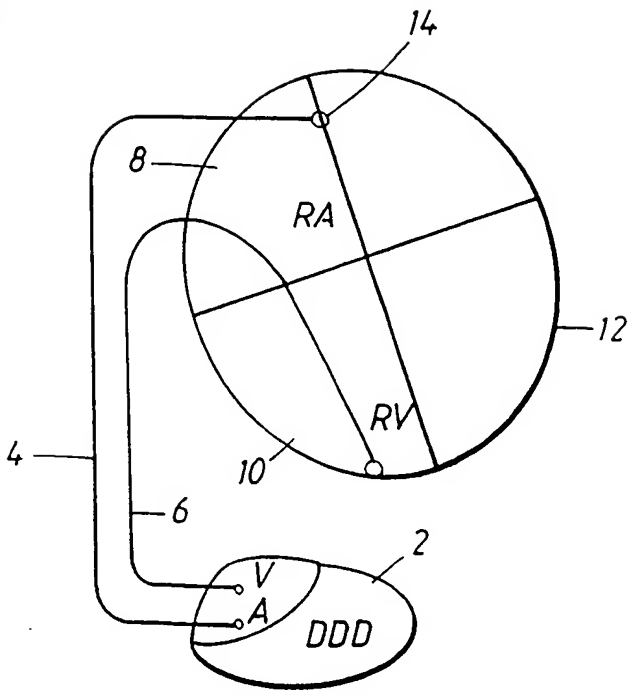


Fig.2

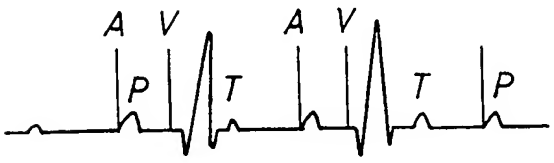


Fig.3

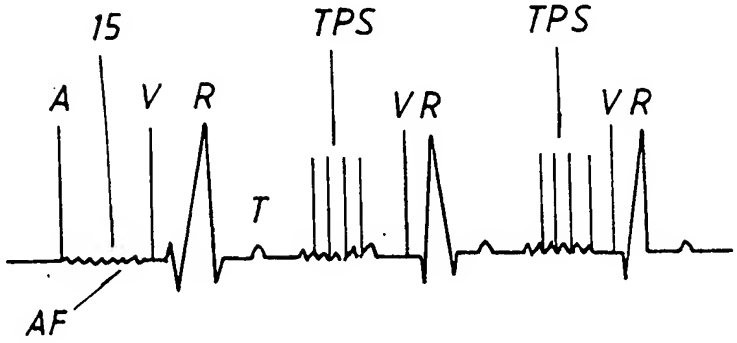
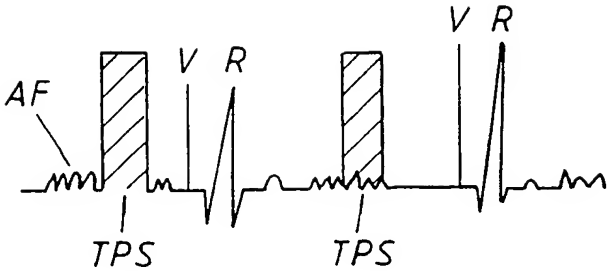


Fig. 4



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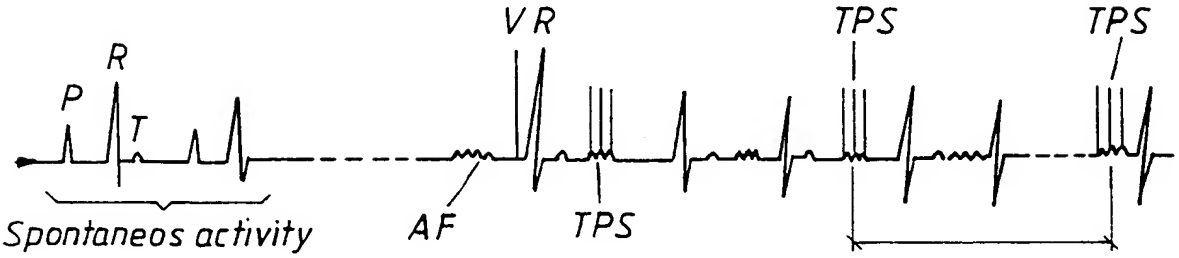

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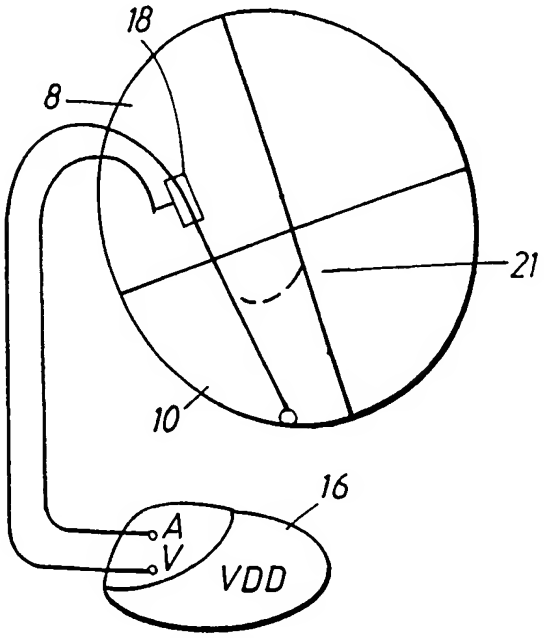


Fig. 7

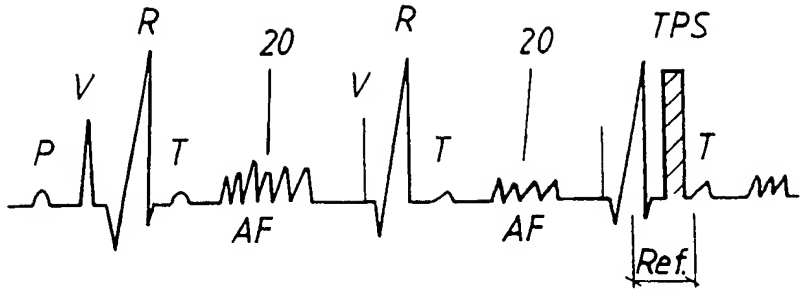


Fig. 8

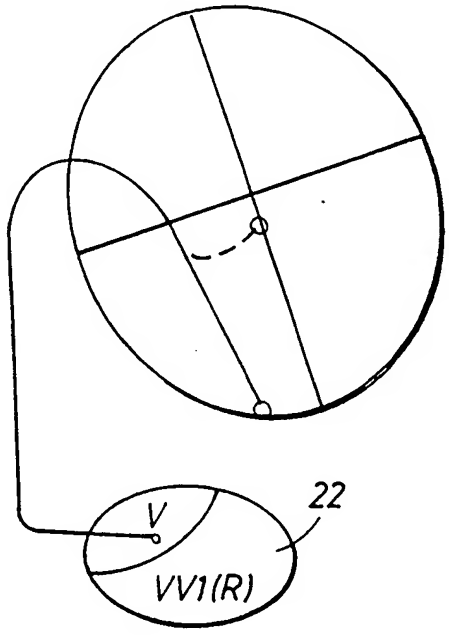


Fig. 9

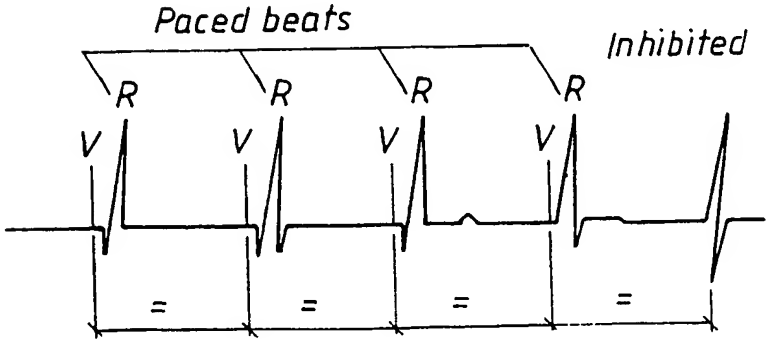
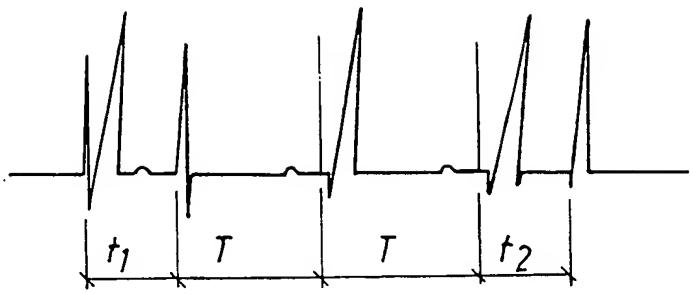


Fig. 10



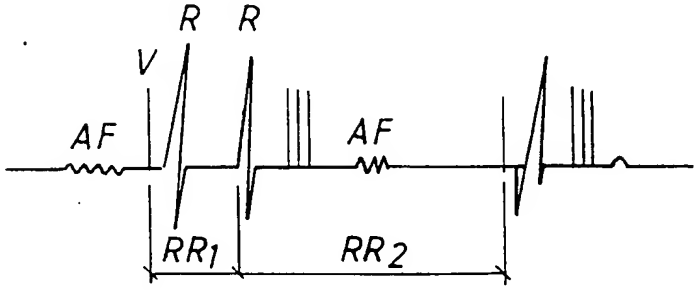


Fig. 11

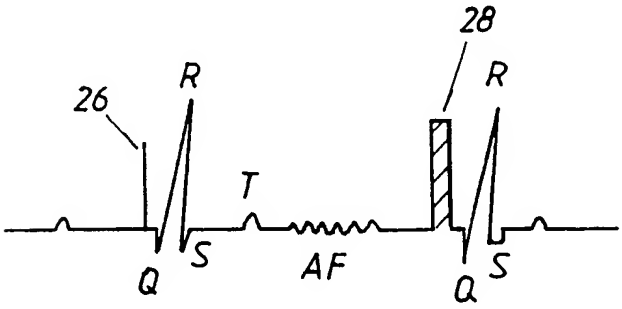


Fig. 12

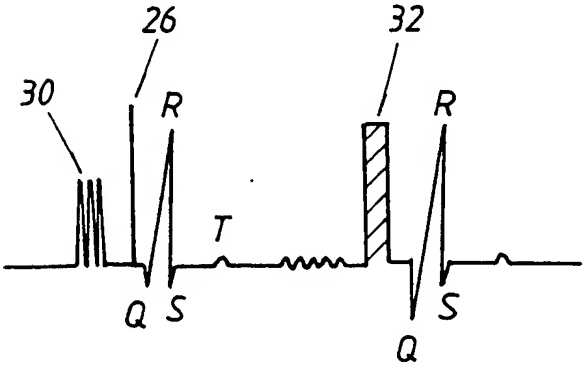
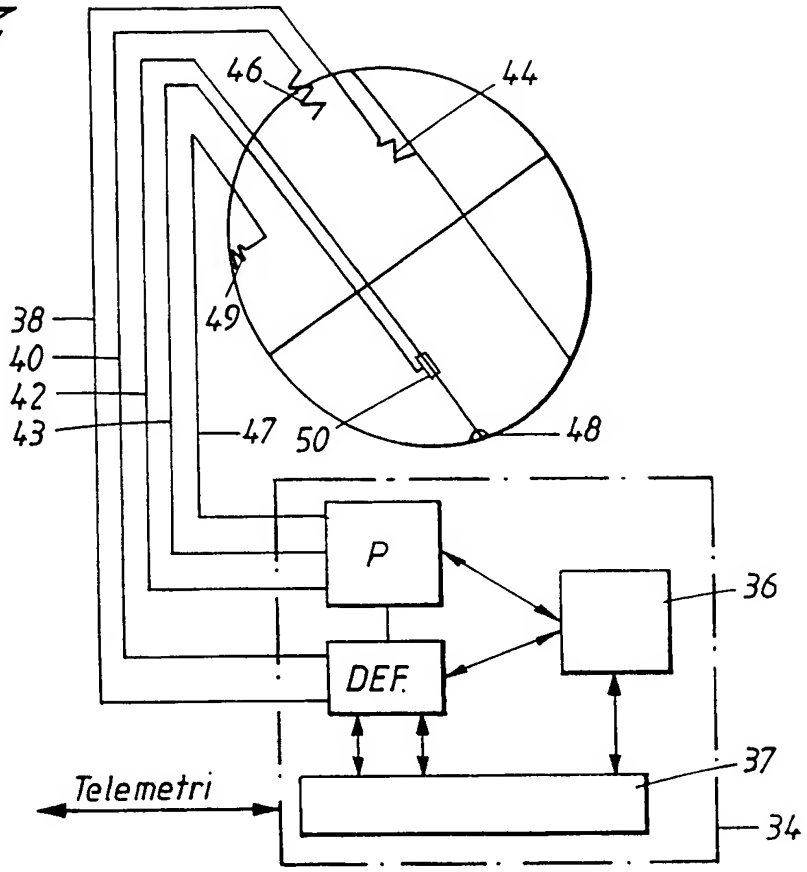


Fig.13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44
49
38
40
42
43
47
50
48
P
36
DEF.
37
Telemetri
34

Fig.14

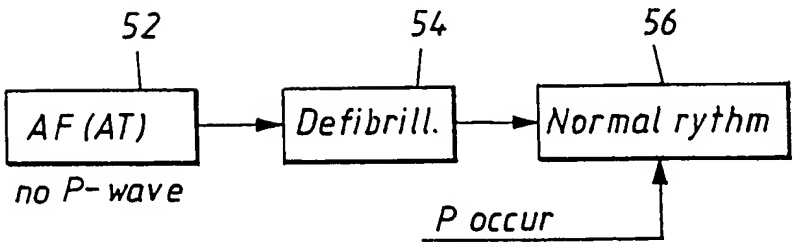

52
54
56
AF (AT)
Defibrill.
Normal rythm
no P-wave
P occur

Fig. 15

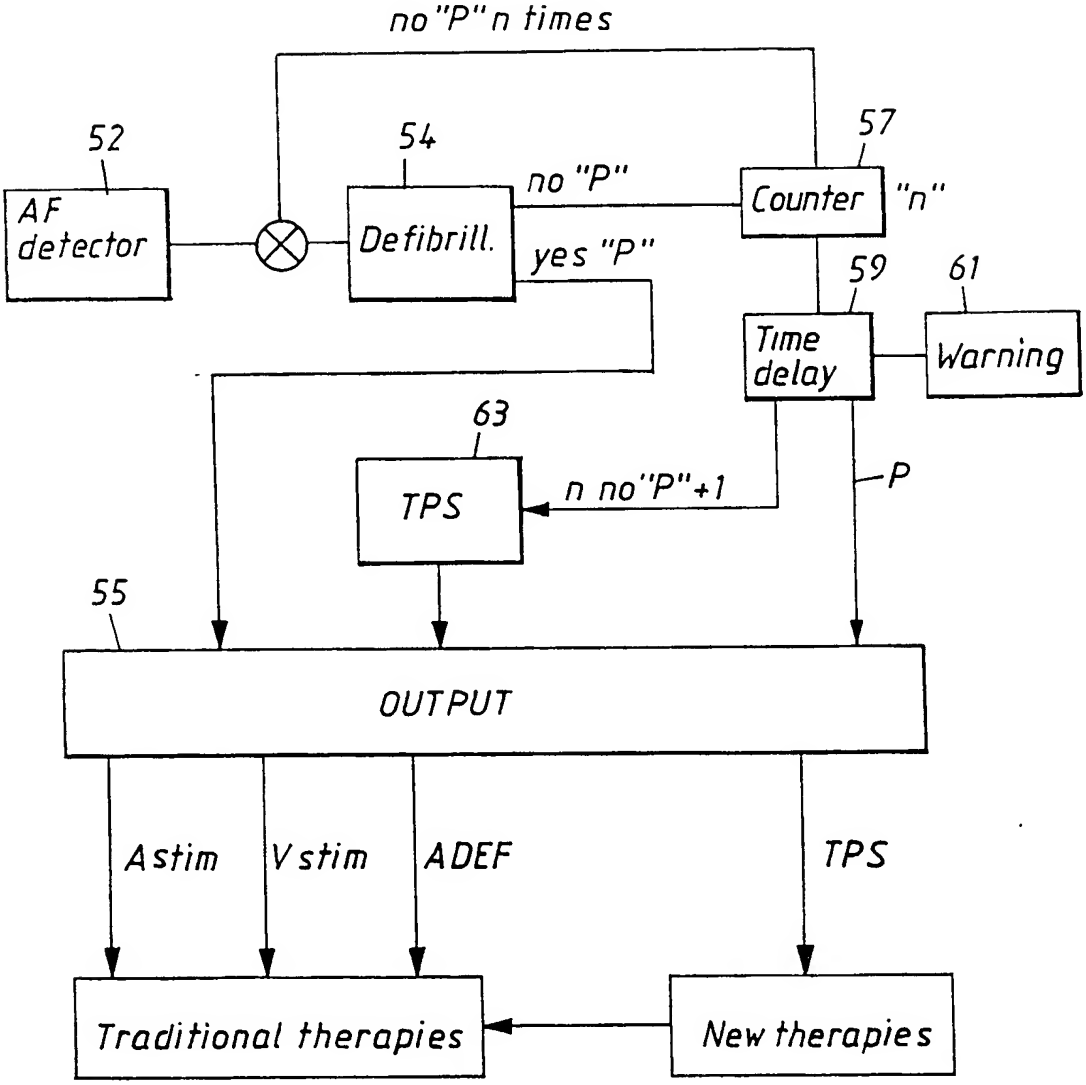
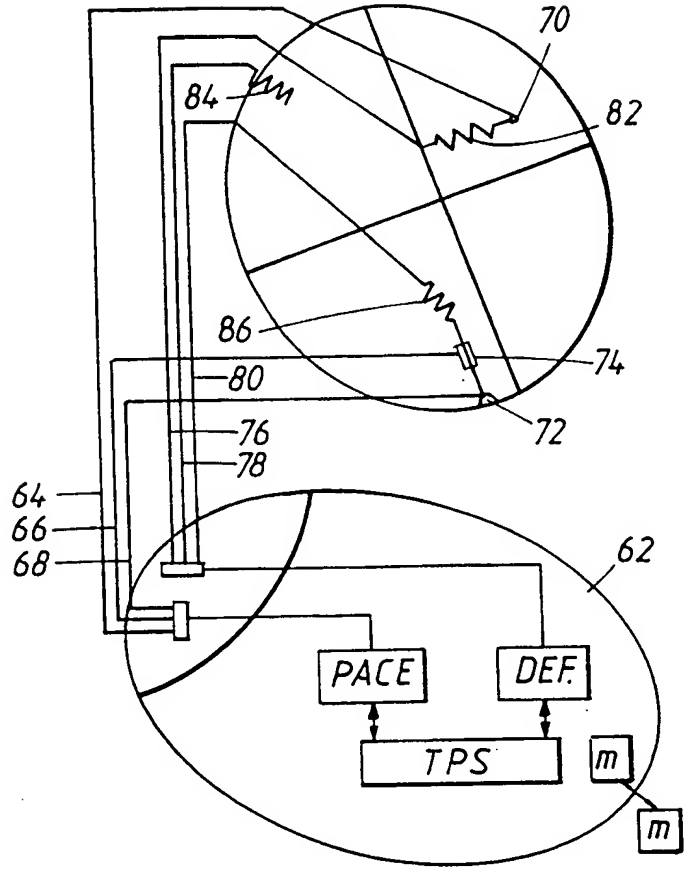

no "P" n times
52
AF detector
54
Defibrill.
no "P"
yes "P"
57
Counter
"n"
59
Time delay
61
Warning
63
TPS
n no "P" +1
P
55
OUTPUT
Astim
Vstim
ADEF
TPS
Traditional therapies
New therapies

Fig.16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84
82
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72
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78
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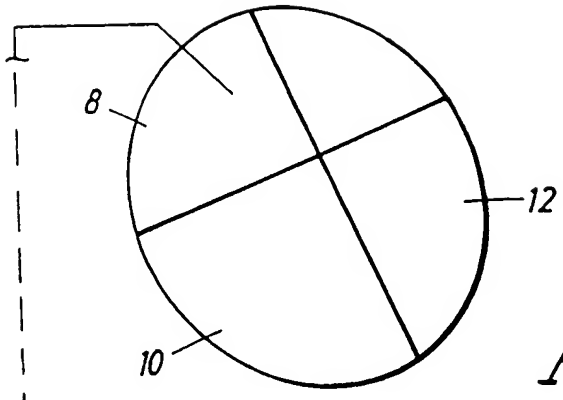
66
68
62
PACE
DEF.
TPS
m
m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10

Fig.17

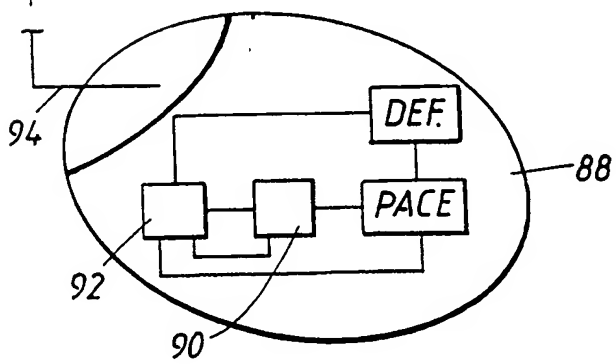

94
DEF.
88
PACE
92
90

Fig.18

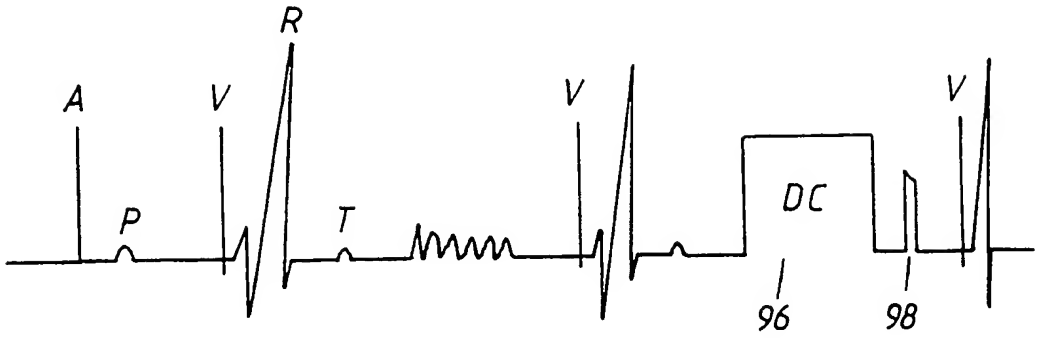
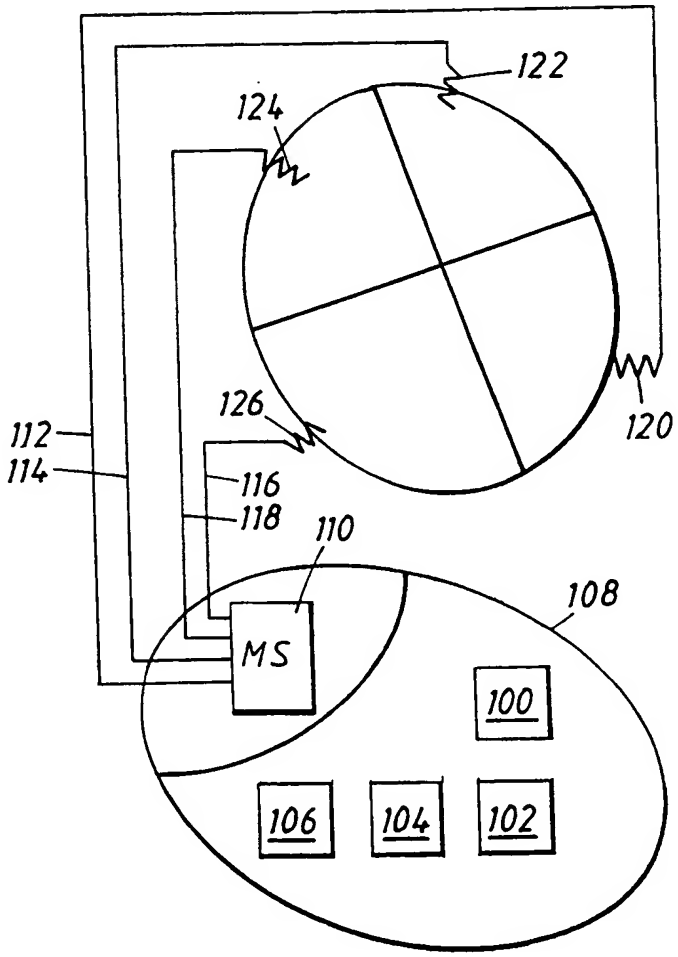

A
P
V
R
T
V
DC
V
96
98

Fig.19


122
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126
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112
114
116
118
110
108
MS
100
106
104
102

Fig. 20

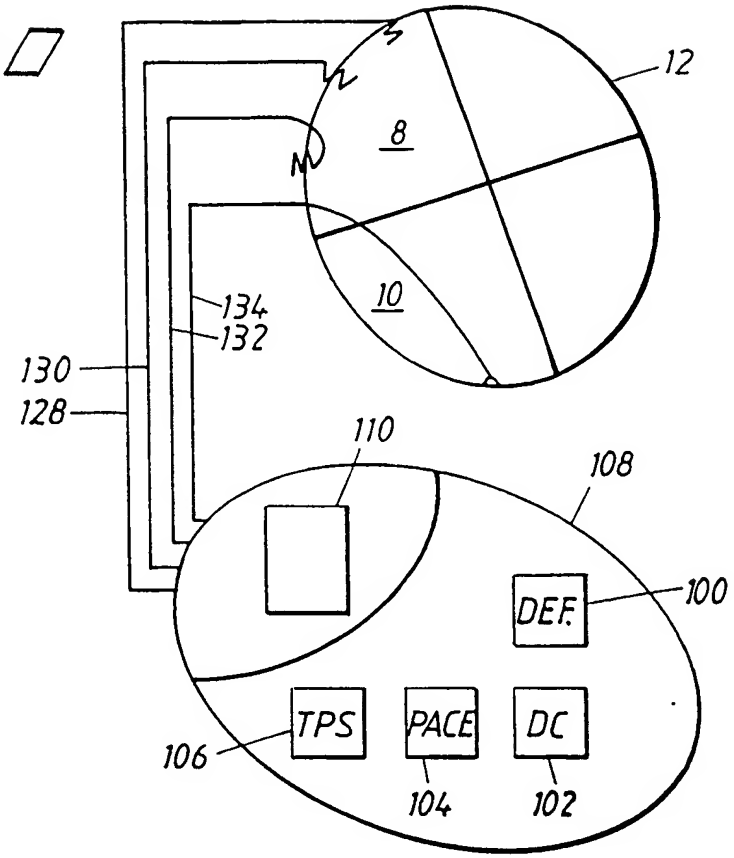

12
8
10
134
132
130
128
110
108
DEF.
100
TPS
PACE
DC
106
104
102

Fig. 21

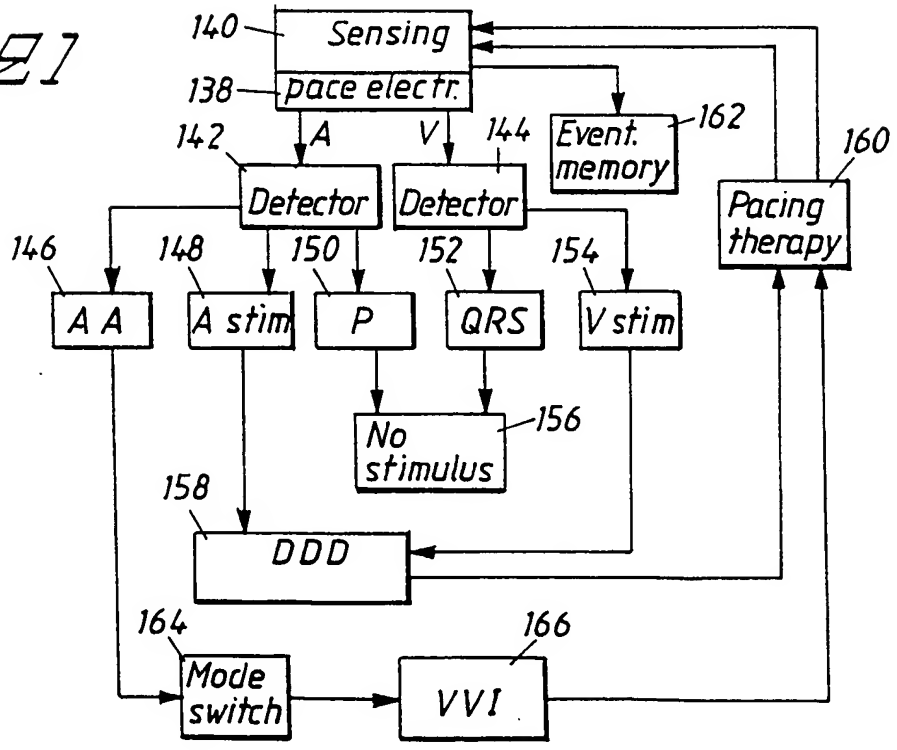

140
Sensing
138
pace electr.
142
A
V
144
Event. memory
162
160
Detector
Detector
Pacing therapy
146
148
150
152
154
A A
A stim
P
QRS
V stim
No stimulus
156
158
DDD
164
166
Mode switch
VVI

Fig 22

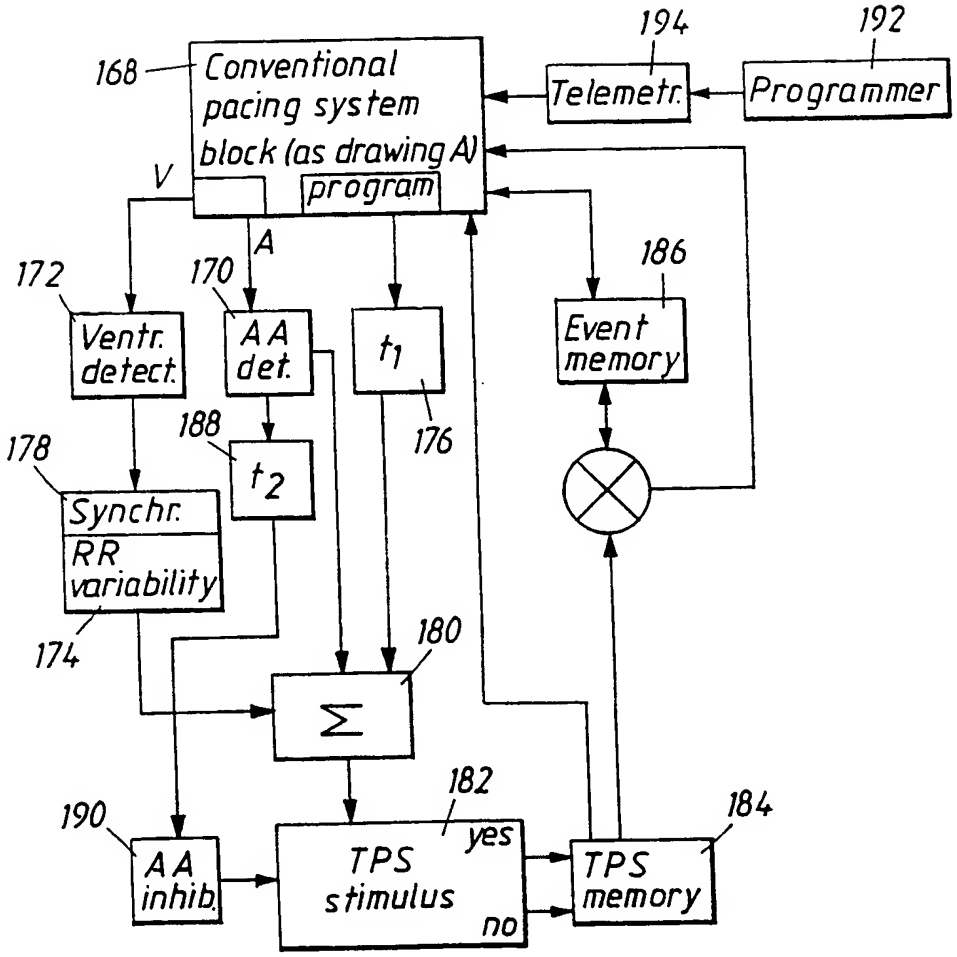

168
Conventional pacing system block (as drawing A)
program
V
A
194
Telemetr.
192
Programmer
172
Ventr. detect.
170
AA det.
t_1
176
186
Event memory
188
t_2
178
Synchr.
RR variability
174
180
Σ
182
yes
no
TPS stimulus
184
TPS memory
190
AA inhib.

Fig. 2A

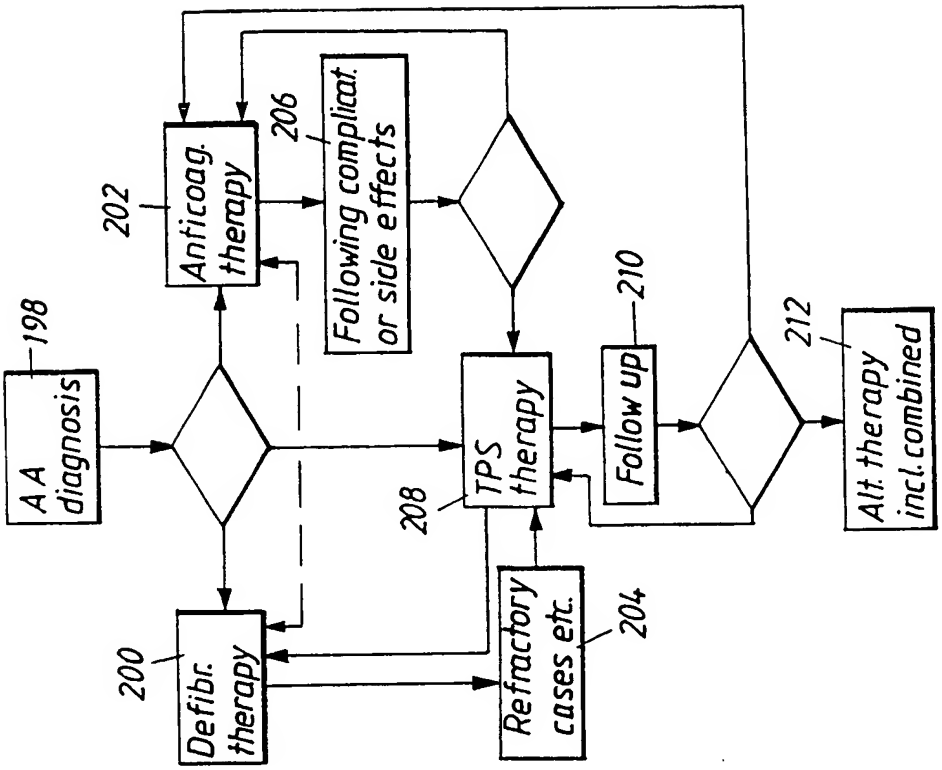
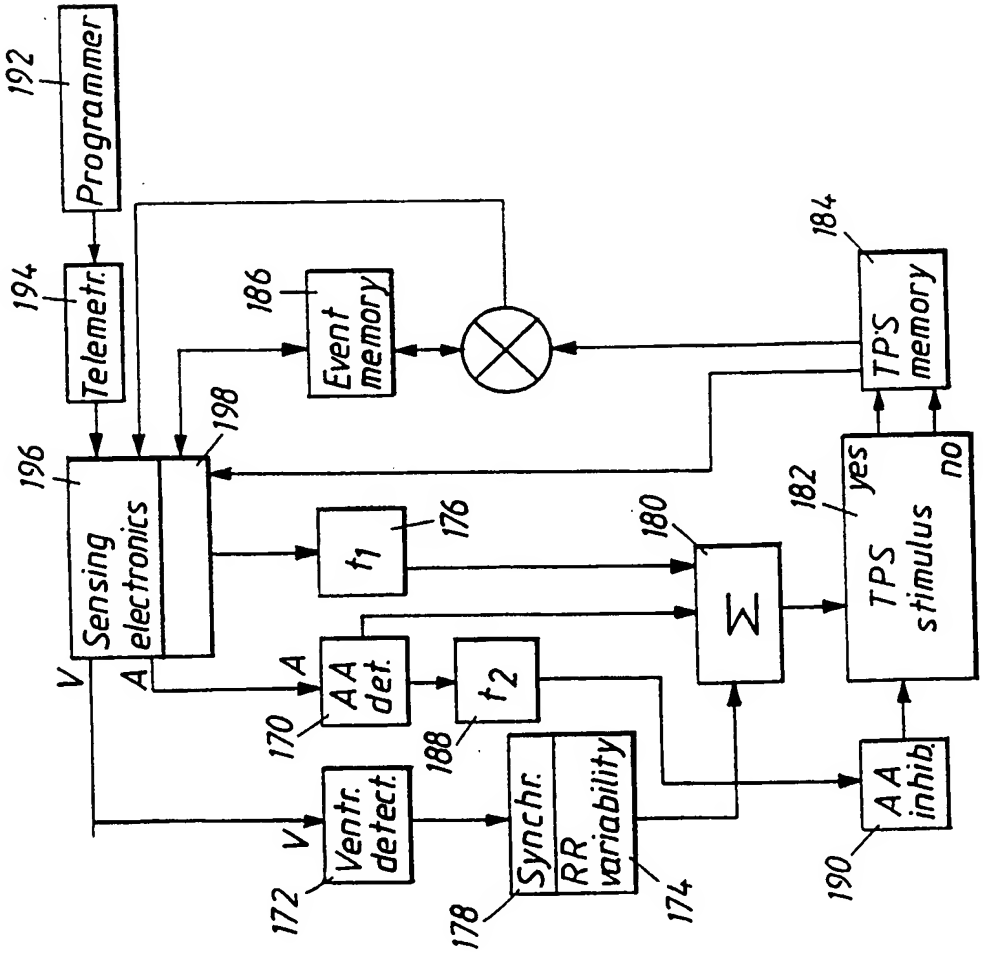

AA diagnosis
198
Anticoag. therapy
202
Following complicat. or side effects
206
Defibr. therapy
200
Refractory cases etc.
204
TPS therapy
208
Follow up
210
Alt. therapy incl. combined
212

Fig. 2B


Programmer
192
Telemetr.
194
Event memory
186
TPS memory
184
Sensing electronics
196
198
V
A
t1
176
AA det.
170
t2
188
Ventr. detect.
172
Synchr. RR variability
178
174
Σ
180
TPS stimulus
182
yes
no
AA inhib.
190

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01822

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: A61N 1/38, A61N 1/365
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: A61N, A61B, A61H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3703900 A (M.A. HOLZNAGEL), 17 February 1999 (17.02.99), abstract ---	1-40
Y	CN 1107034 ((HEBE-N)HEBEI POLYTECHNIC COLLEGE), 23 August 1995 (23.08.95), abstract, line 4-6 ---	1-40
A	US 5433729 A (J.M. ADAMS ET AL.), 18 July 1995 (18.07.95), see the whole document --- --------	1-40

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 February 1999	19 -02- 1999
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Joni Sayeler Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/02/99

International application No.
PCT/SE 98/01822

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 3703900 A	17/02/99	NONE	
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